Compact Superfluid Cooling System (CSC) for the Superconducting Magnet of AMS II

by

H. Hofer, B. Blau (ETH Zürich),

A. Grechko (Kurchatov Institute), S. Harrison (SCL)

Main CSC Requirements

Cold mass (magnet, He vessel, etc.)…………………..~ 2000 kg

Temperature range of cooling………………………..300 - 1.8 K

Max. temperature gradient during cool down

at the range 300-90 K…………………………………50 K

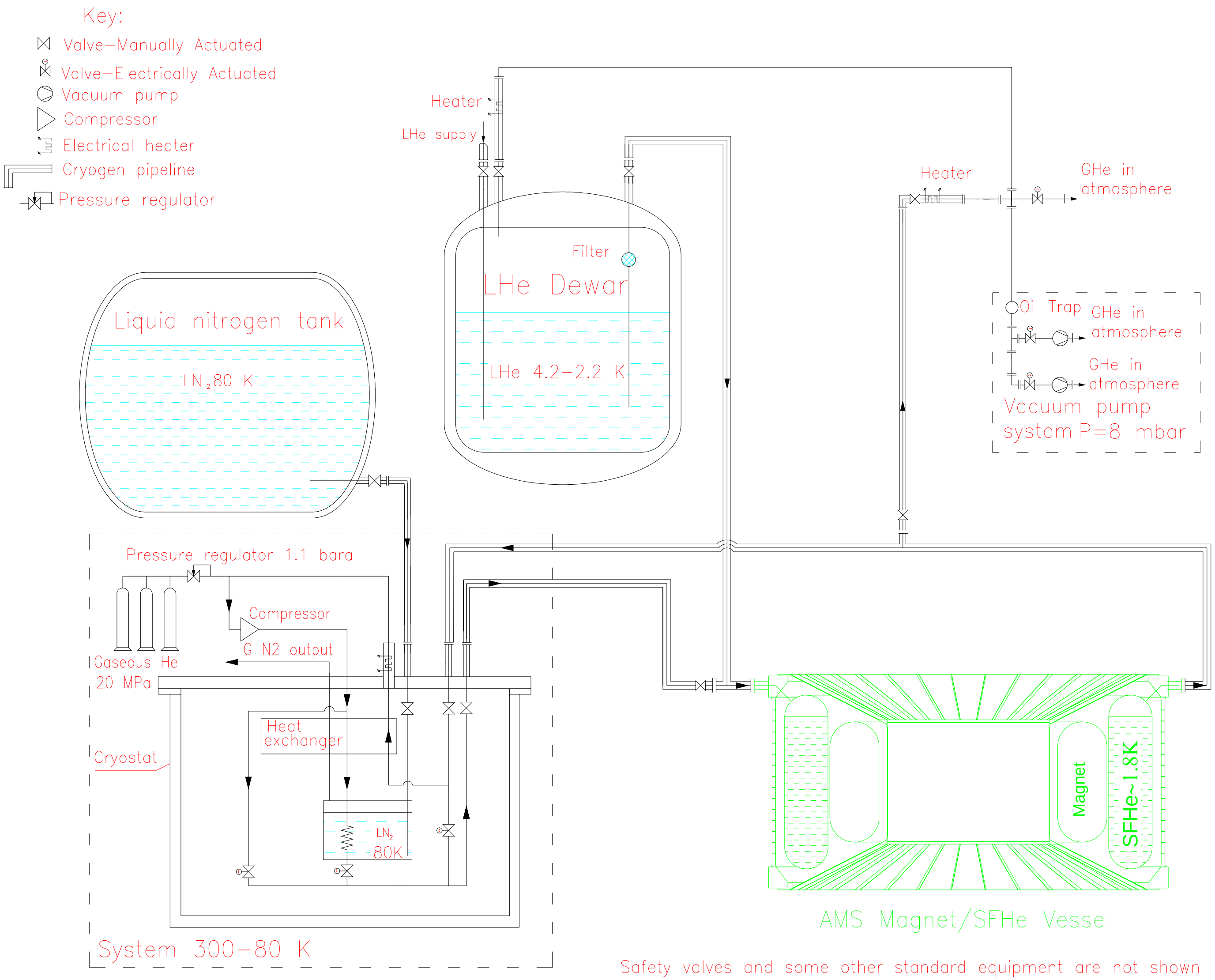
Kind of magnet cooling………………………………..indirect

Volume of magnet helium vessel…………………….~ 2500 l

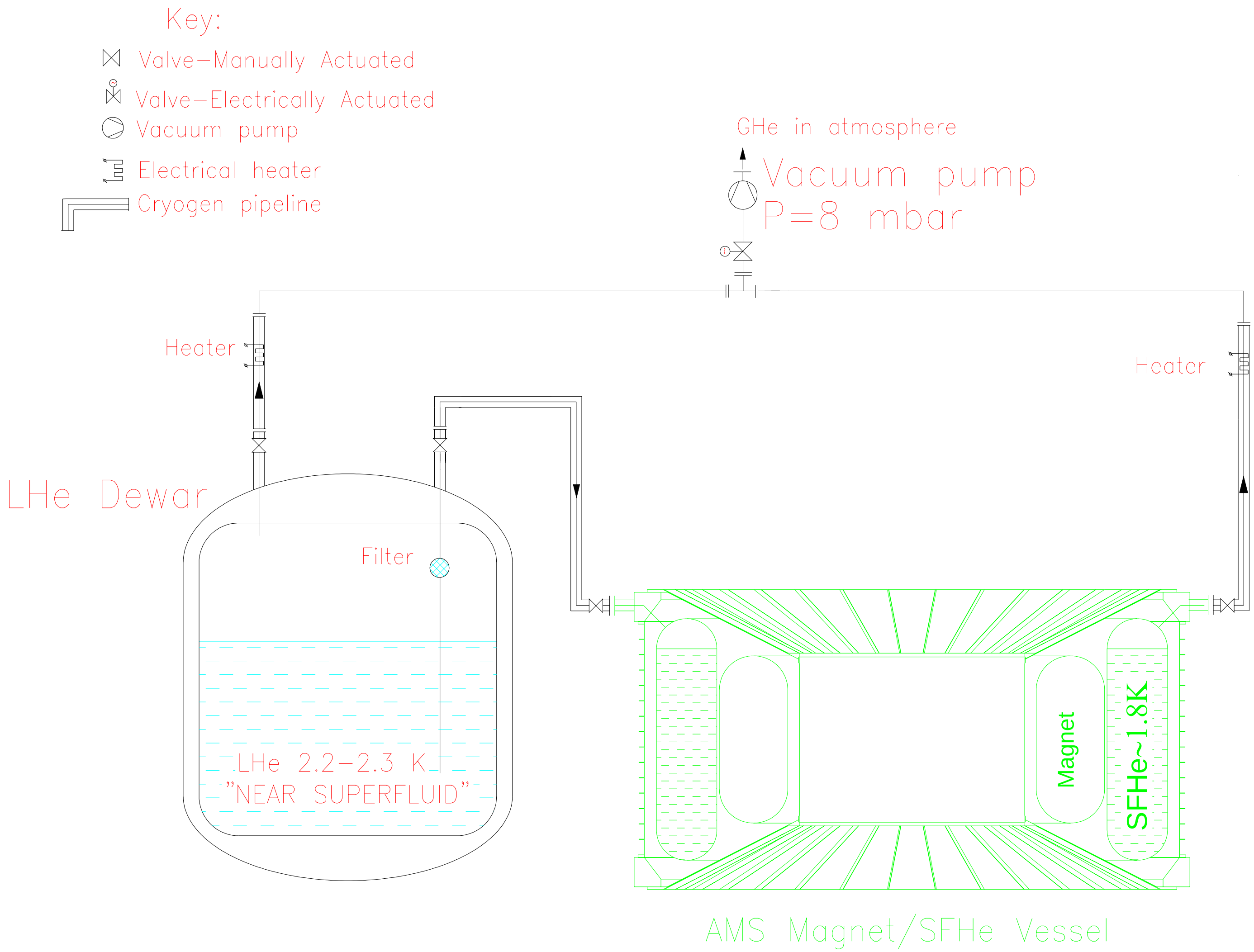
Max. pressure in helium vessel……………………..1.6 bar

Movable…………………………………………………yes

CSC Simplified Scheme

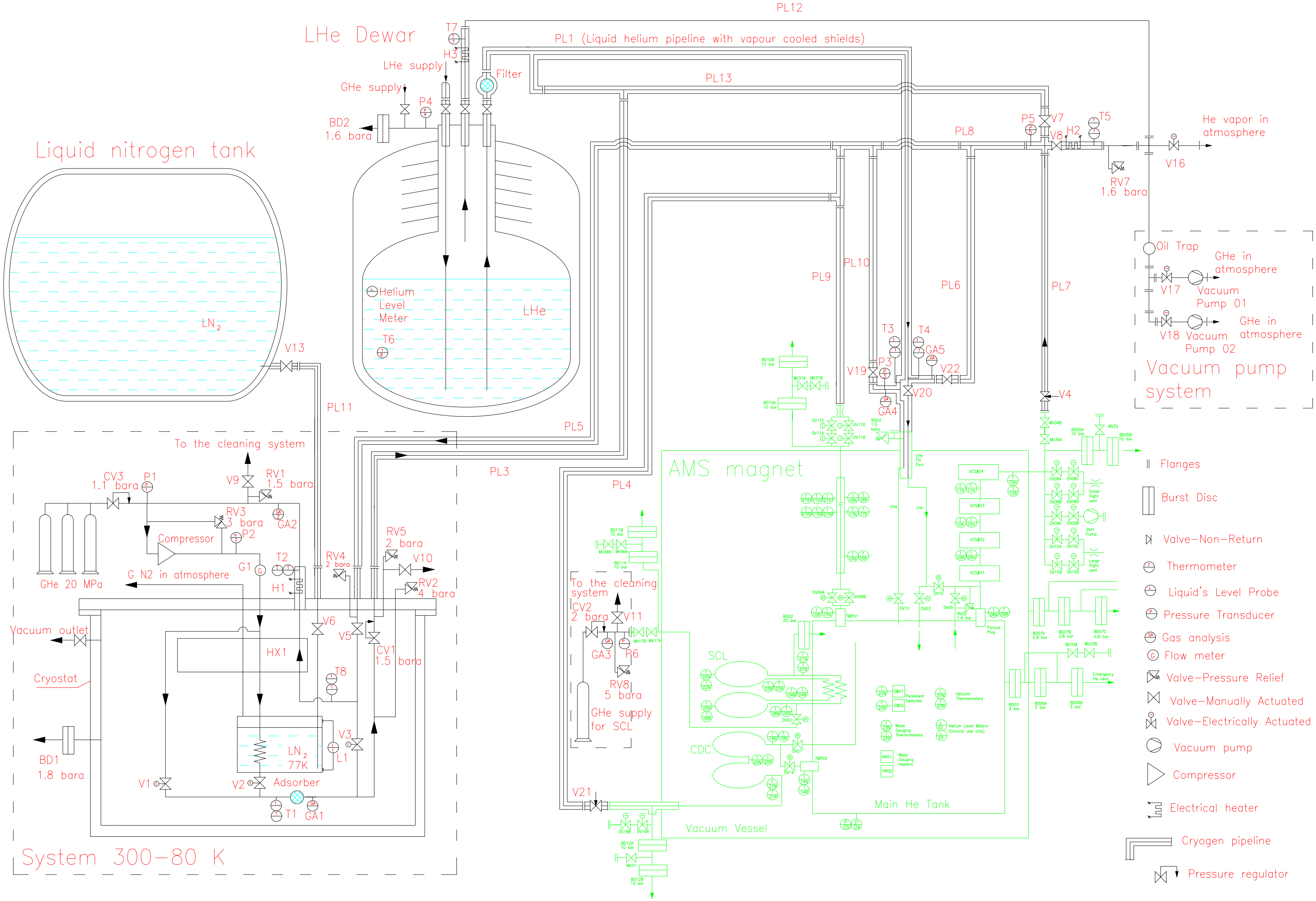


Top-up of AMS Magnet with SFHe at the Launch Pad



Safety valves, sensors and some other standard equipment are not shown

CSC Principal Scheme



List of CSC Systems and Devices

1. System for controlled cool down and warm up in the temperature range 300-80 K
2. System for filling Superfluid Cooling Loop of AMS magnet with liquid He
3. Vacuum pump system
4. Liquid He Dewars
5. Liquid nitrogen tank
6. Cleaning system for removing impurities from the system and providing high purity of He flow
7. Measuring and control system
8. Cryogen pipes and armature

System for Controlled Cool Down and Warm up in the Temperature Range 300-80 K

- Cryostat with heat exchanger, liquid nitrogen bath (flow rate of liquid nitrogen vaporization 11 g/s), valves, heater 2.5 kW and absorber of impurities
- Clean helium compressor system with total capacity about 2 g/s. Main feature – without contamination of circulating He with any impurities (oil, water, air)
- Warm helium supply (battery of cylinders with pressurized gaseous He) for compensation of increasing He density during cool down (4 standard 40 l cylinders)
- Liquid nitrogen supply

KNF's Membrane Compressor

Features:
- greatly increased safety with the double diaphragm system
- leak rate less than 6 x 10^{-6} mbar/ls
- small dimensions and easy installation
- free of oil and maintenance-free
- designed for simultaneous under-pressure and over-pressure

Type	Delivery (l/min)*	Ultimate vacuum (mbar abs.)	Max. operating pressure (bar g)	Weight (kg)
N 150.1.2 __.12E	280	100	2	30
Depending on the design, individual pump types may feature different performance values. Performance details relate to the 220 V version.				

http://www.knf.de/e/index.htm

System for Filling Superfluid Cooling Loop of AMS Magnet with Liquid He

- Warm helium supply (battery of cylinders with pressurized gaseous He or He gasification system, may be joined with the same system for cool down 300-80K, 7 standard 40 l cylinders are required)
- Reducer of pressure and valve for control pressure at the output not more 2 bara
- Sensors (pressure and gas analysis)
- Output to the cleaning system

Vacuum Pump System Requirements

Two vacuum pump each with capacity not less 2 g/s or 2770 m^3/hour He at 293 K and 800 Pa. Output pressure 1 bar. Must be transportable by plane. Must be compatible with European (50 Hz) and American (60 Hz) power supply

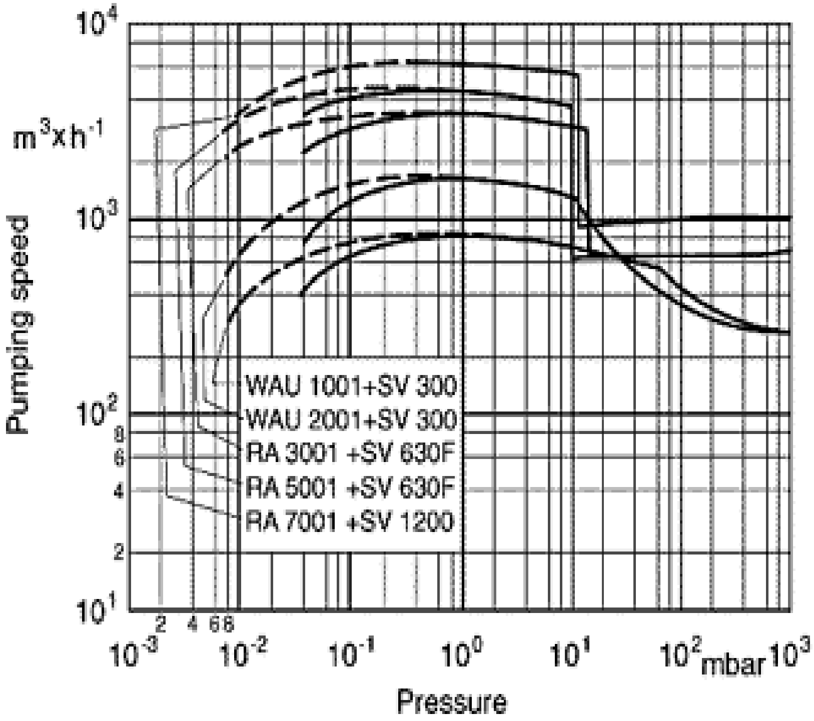
Available Vacuum Pumps Technical Data

Technical Data		Leybold RUTA	
		2001/SV300/G	7001/SV1200/G
RUVAC RA	P2	–	7001
RUVAC (WA/WAU/WS/WSU possible)	P2	2001	–
SOGEVAC backing pump	P1	SV 300	SV1200
Pumping speed at 10^{-1} mbar	$m^3 \times h^{-1}$ (cfm)	1445 (850)	5520 (3250)
Ultimate partial pressure	mbar (Torr)	$< 8 \times 10^{-3}$ ($< 6 \times 10^{-3}$)	$< 9 \times 10^{-3}$ ($< 6.75 \times 10^{-3}$)
Ultimate partial pressure with gas ballast	mbar (Torr)	$< 4 \times 10^{-2}$ ($< 3 \times 10^{-2}$)	
Installed motor power	kW	13	33.5
Power consumption at 10^{-1} mbar	kW	4.5	18
Noise level to DIN 45 635 without gas ballast at 10^{-1} mbar	dB(A)	79	82
Oil filling, total, approx.	l	13	62
Weight, total, approx.	kg (lbs)	740 (1631.7)	3000 (6615)
Connecting flanges			
Inlet port	DN_1	160 ISO-K	250 ISO-K
Outlet port	DN_2	2"	160 ISO-K

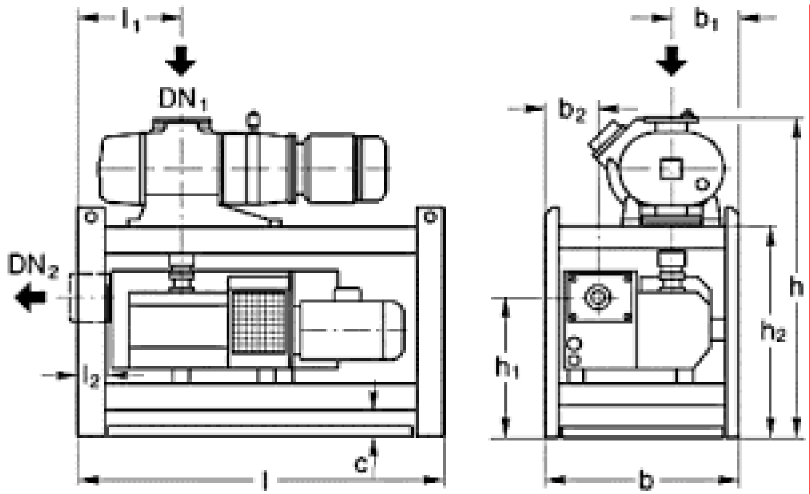
Available Vacuum Pumps Leybold RUVAC RA2001/SV300 and RA7001/SV1200

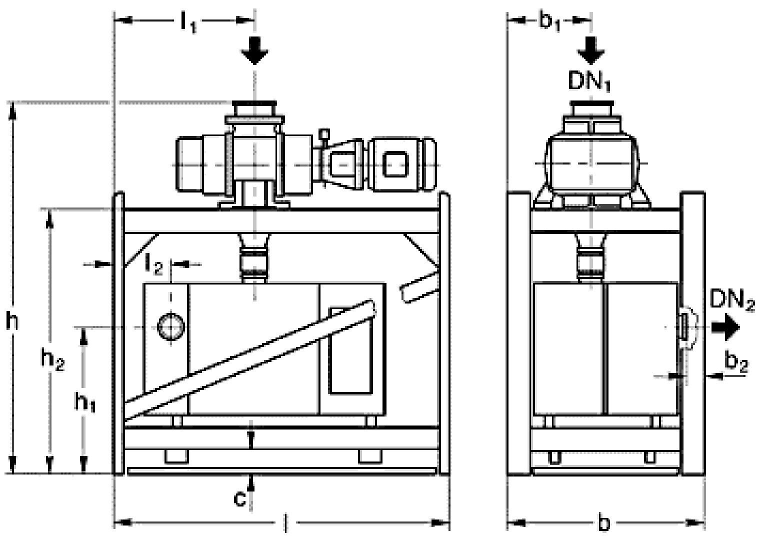
RUTA WAU 2001 / SV 300 / G

Pumping speed diagram



Dimensional Drawings for the Vacuum Pumps





	RUTA	2001/SV300/G	7001/SV1200/G
RUVAC RA	P2	–	7001
RUVAC WA/WAU/WS/WSU	P2	2001	–
SOGEVAC backing pump	P1	SV 300	SV 1200
	DN$_1$	160 ISO-K	250 ISO-K
	DN$_2$	2"	160 ISO-K
	l	1340	2325
	l_1	380	975
	l_2	110	405
	b	780	1360
	b_1	320	580
	b_2	191	158
	h	1259	2580
	h_1	518	1020
	h_2	729	1835
	c	100	

Cleaning System

- Helium leak detector
- For-vacuum pump with capacity 50 l/s and vacuum 10^{-3} mm Hg
- Warm helium supply (battery of 12 cylinders with pressurized gaseous He)
- Set of flexible piping and valves
- Connection to the gas analysis system

Measuring and Control System

- Gas analysis system for control of He purity. Requirements to purity of He: nitrogen<10^{-5} %, neon<10^{-5} %, hydrogen<10^{-5} %, hydrocarbons<0.1 ppm
- For system 300-80 K: Flow rate of He. Range of measurement 0.5-2.5 g/s; Controlled mixing of cold and warm flows to provide required temperature difference (no more 50 K) between magnet's input and output of helium flow; Control of the level of liquid nitrogen; Control power of heater H1 to maintain helium output flow temperature not less 290 K (the same for heaters H2, H3)
- He flow temperature sensors (8 points of measuring)
- Pressure sensors (6 points).
- Capability to display sensors read-out and state of the system, capability of writing sensors readout into memory that it will be possible to see changes of parameters by time and for data archiving.
- Capability to control the valves
- Sensors and valves that locate near AMS magnet, must work in magnetic field
- Capability to monitor magnet temperatures (interface TBD)
- Warning and alarm conditions to be recognized and displayed
- Capability to abort cool down safety under alarm conditions

Liquid He Dewars and Liquid Nitrogen Tank Requirements

- Two 1000 l He Dewars must be transportable by plane, equipped with LHe level probes, temperature sensors of the LHe for range 4.5-1.8 K, possibility to pump He to 1600 Pa, filter for separation solids parts to avoid impurities go to the AMS magnet (should be installed at the pipeline for filling AMS magnet with LHe).
- Liquid nitrogen tank 3500 l. Must be transportable by plane

Tank for Liquid Nitrogen

Technical Data

Capacity (ltr)	3500
Length (mm)	3750
Diameter (mm)	1500
Height (mm)	1725
Weight Empty (kg)	1500
Weight Full LN2 (kg)	4330
Maximum Working Pressure (bar)	3.0
Static Evaporation Rate (% per day)	0.6

Liquid Helium Dewar

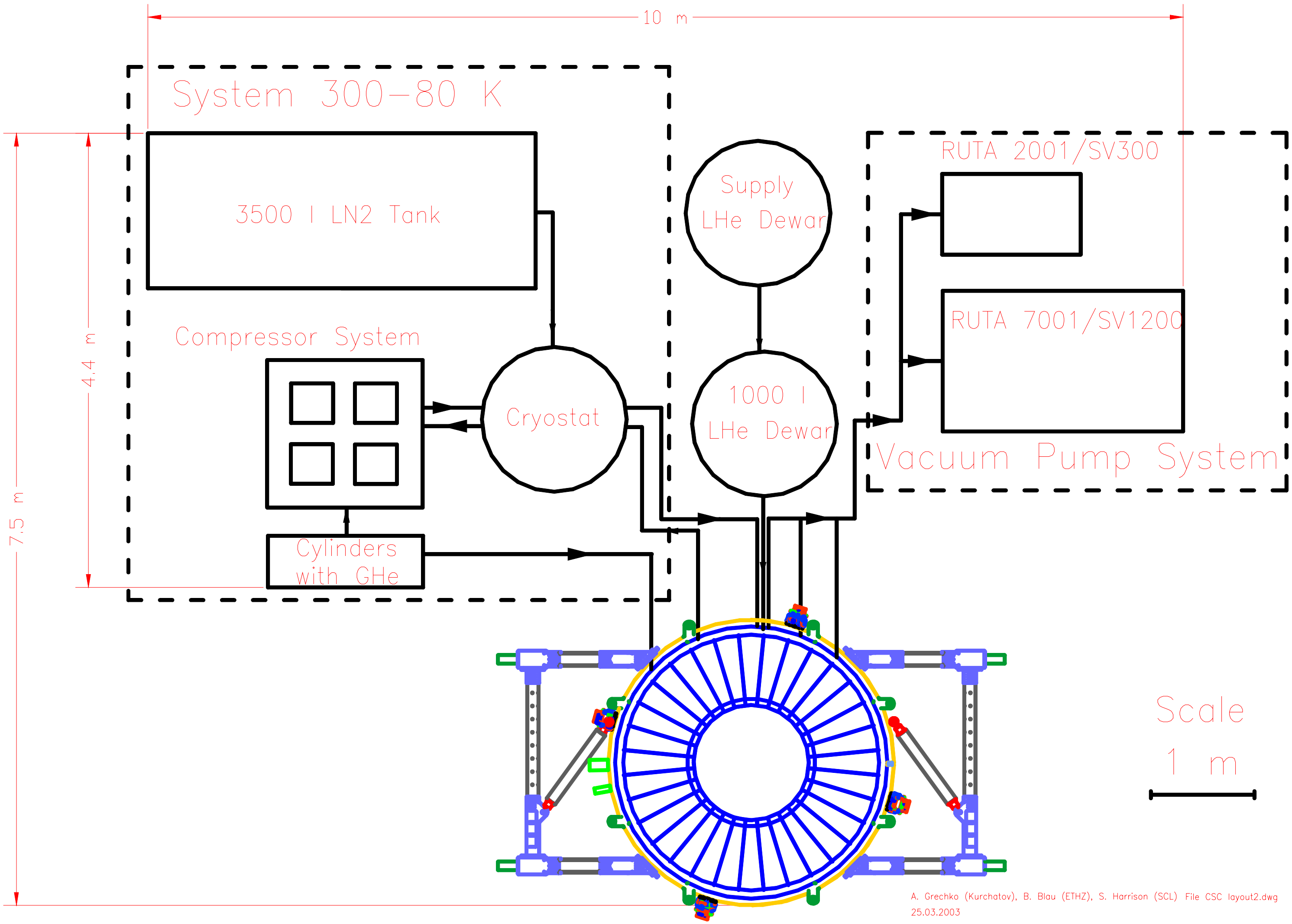
Technical Data

Net Capacity (ltr)	950
Diameter (mm)	1400
Height (mm)	1765
Weight Empty (kg)	650
Weight Full LHe (kg)	770
Maximum Working Pressure (bar)	0.5
Static Evaporation Rate (% per day)	0.4

Cryogen Pipes and Armature Requirements

As low as possible heat flux to the helium flow (especially to liquid helium from Dewar to AMS magnet), flexibility, possibility to change length if needed (by adding pieces), convenient for mounting and dismounting, supports for valves and pipe (no loading allowed on AMS magnet construction and fill ports).

CSC Schematic Layout



Liquid He and N_2 Consumption for One Cool Down and Filling with SFHe*

Mode	Regime	Cooling source	Enthalpy difference of cold mass [MJ]	Enthalpy difference of He mass [MJ]	Liquid He consumption		Liquid N_2 consumption	
					Mass of He [kg]	Volume of He [m^3]	Mass of N_2 [kg]	Volume of N_2 [m^3]
1	Cooling from 300 to 80 K	Liquid nitrogen	323	-	-	-	1620	2.0
2	Cooling from 80 to 4.2 K	Evaporation of liquid He and heat capacity of cold He gas	13.3	-	62	0.5	-	-
3	Filling with liquid He at 4.2 K	-	-	-	313	2.5	-	-
4	Cooling from 4.2 to 1.8 K and top-up	Pumping of He	0.0014	4.06	250	2.0	-	-
Total			336.3	4.06	625	5.0	1620	2.0

* Estimation using m_{cold} = 2000 kg, V_{He} = 2.5 m^3 and ideal case without losses. For redundancy the numbers of consumptions should be multipled by factor 1.5